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Research Article
Influence of Biofertilizer on Soil Properties, Growth and Yield of Hot Pepper (*Capsicum frutescens*) in Calabar, Cross River State, Nigeria

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Abstract
Background and Objective: The inability of NPK fertilizer to optimize crop yield over a long time without environmental pollution prompted this study on bio-fertilizer production through anaerobic digestion utilizing cow dung (C), banana (B), watermelon (W) and paw-paw (P) fruit peels and its effect on soil properties, growth responses and yield of hot pepper. **Materials and Methods:** A field experiment was carried out during the dry and wet seasons in 2015/2016 cropping year in University of Calabar Teaching and Research Farm. The treatment comprised 11 bioslurry and two control replicated three times and laid out in Randomized Compete Block Design. **Results:** The result obtained showed an increase in soil pH for W, B+W, C+W, B+P and C+P (6.1-6.5), W+P and W+C+P+B (6.7-6.8) and C+B and C (7.8-8.2) amended soil compared with control soils (4.7-4.8). Organic carbon values ($\geq$1.5%) and total nitrogen ($\geq$0.2%) were obtained on amended soils compared with low values on control soils. Except K contents, bio-fertilizer amended soils showed enhancement in Ca ($\geq$ 4.0 cmol kg^{-1}), Mg ($\geq$0.4 cmol kg^{-1}), available P ($\geq$34.4 mg kg^{-1}), CEC ($\geq$7.1 cmol kg^{-1}) and ECEC ($\geq$6.1 cmol kg^{-1}) relative to the unamended or NPK amended soils. Similarly, soils amended with W+C+P+B bio-fertilizer significantly ($p\leq0.05$) produced the tallest pepper plants with highest number of leaves, leaf area index, number of fruit per plant, fresh fruit yield (13.61 t ha^{-1}) and dry fruit yield (1.33 t ha^{-1}). **Conclusion:** The result obtained from the current research indicated that maximum yield of pepper could be achieved from the combination of W+C+P+B bio-fertilizer.

Key words: Anaerobic digestion, bio-fertilizer, hot pepper, NPK fertilizer, yield response

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pepper (*Capsicum* spp.) is the third most important vegetable crop in Nigeria after onions and tomatoes[1]. It is an important source of vitamins A, B_2 and C and a good source of phosphorus and calcium. The nutritional value of hot pepper needs special attention since it is a rich source of vitamin A, C and contains more vitamin C than any other vegetable crop[2].

However, to obtain high-quality fruit and achieve higher yield in pepper, there is a need to supply the soil with proper nutrients and one way of achieving this is through the use of fertilizers[3]. Nevertheless, the use of chemical fertilizers indiscriminately results in polluting water bodies, altering soil pH negatively and also degrading soil quality; impacting negatively on the quantity and quality of crop yield[4,5] and may cause problems on human health. There is, therefore, the need to investigate methods that will maximize crop production in the prevailing farming systems suitable to local farmers and production systems with eco-friendliness. The use of organic materials including agricultural wastes could be found promising.

Agricultural wastes arising from fruits peels like banana, paw-paw, watermelon pineapple etc. and livestock wastes such as; cow dung, poultry manure, pig dung, etc. could be used for the production of bio-fertilizer. Bio-fertilizer is a mixture of plant and animal residues containing micro-organisms which could convert complex organic compounds into simple compounds through their mutualistic interaction with the plant roots for easy absorption of nutrients when they are applied to the soil[4,6]. They colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to host plant[6].

Through the principle of anaerobic digestion, useful products such as; renewable energy (biogas) and residual bioslurry could be generated by methanogens and these principles prevent the transmission of diseases within the environment[7,8]. The Anaerobic Digestion Effluent (ADE) contains mineralized plant nutrients that can replace the input of synthetic fertilizers and can boost the yield of crops[9].

The benefit and importance of bio-fertilizer in Agriculture cannot be overemphasized. In several studies, the effect of bio-fertilizer has been implicated to significantly increased pepper plant height, leaf number, fruit number, fruit weight and fruit yield[10-12]. However, in most of these studies, changes in soil properties were not reported; their investigations were skewed to assessing the effect of bio-fertilizer on crop growth attributes and yield. Hence, there is a paucity of information on the effect of bio-fertilizer on soil properties.

Studies on various crops have shown that the balanced use of NPK fertilizer alone could not optimize the needed crop yields over a long time, especially under a hot humid climate environment characterized by extremely high temperatures and excessively high rainfall[13]. According to Amalu and Isong[13], under such prevailing environmental conditions, nutrient leaching and volatilization are inevitable. Conversely, the use of only organic manures cannot also satisfy the immediate crop nutrients requirement due partly to its slow-releasing effect[14]. Deore *et al.*[15] recommended that applying organic manures with chemical fertilizers would result in better yield than when using a single nutrient source. This study justifiably explored the use of bio-fertilizer from organic wastes such as; cow dung, banana peels (*Musa acuminata*), watermelon peels (*Citrullus lanatus*) and paw-paw peels (*Carica papaya*) as soil amendment and NPK inorganic fertilizer and their effect on soil properties, growth responses and yield of hot pepper.

MATERIALS AND METHODS

The research was conducted at the University of Calabar Teaching and Research Farm during 2015/2016 wet and dry cropping seasons. The farm lies between Latitudes 4°56′ and 4°59′ N and Longitudes 8°20′ and 8°21′ E within the tropical rainforest agro-ecology of the equatorial climatic belt of Nigeria and is 39 m above sea level (Fig. 1). It receives a bimodal annual rainfall that exceeds 2,500 mm with severe leaching of nutrients from the soils. The annual temperature ranged from 22.2-32°C with relative humidity[16] of 75-90%.

Hot pepper seeds (*Capsicum frutescens* cv. Angel F1) obtained from agro-chemical shop in Enugu state, Nigeria, was used for the experiment. Bio-fertilizers were produced from microbial digested watermelon (*Citrullus lanatus*), paw-paw (*Carica papaya*) and banana (*Musa acuminata*) fruit peels and cow dung following anaerobic digestion process in digester[17,18]. The substrates from fruit peels and cow dung in both single and combined forms were mixed at a ratio of 1:3 (substrates 13 kg and water 39 kg w/w) and placed in different digesters[18].

The experiment was laid out in a Randomized Complete Block Design (RCBD). The treatments consisted of 11 bioslurry and control (NPK 15:15:15 and no fertilizer and bioslurry application) (Table 1) each replicated 3 times, giving a total of 39 treatments. Each experimental plot was 6 m^2 (3×2 m) in both seasons with 0.5 m between plots and 1 m pathway. The planting distance adopted in both seasons was 60 cm

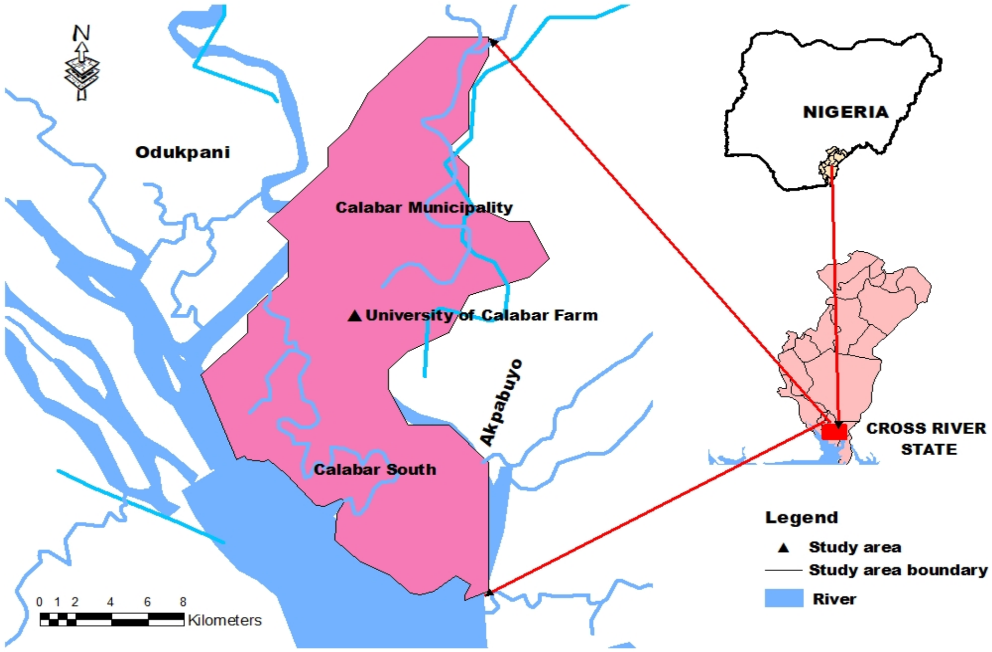

Fig. 1: Map of Calabar metropolis showing study area

Table 1: Treatments description used in study

Treatments description	Treatments designation	Application rate per ha (L ha^{-1})	Application rate per plant (L/plant)
Cow dung (C)	C (13 kg)	14,286	0.343
Water melon peels (W)	W (13 kg)	47,058.82	1.13
Paw-paw peels (P)	P (13 kg)	23,529.41	0.565
Banana peels (B)	B (13 kg)	47,058.82	1.13
Water melon peels+Cow dung (W+C)	½ W+ ½C	44,444.44	1.07
Water melon peels+Paw-paw peels (W+P)	½ W+½P	47,058.82	1.13
Water melon peels+Banana peels (W+P)	½ W+½B	72,727.27	1.745
Cow dung+Paw-paw peels (W+P)	½ C+ ½P	17,778	0.427
Cow dung+Banana peels (C+B)	½ C+ ½B	11,940.30	0.286
Paw-paw peels+ Banana peels (P+B)	½ P+½B	47,058.82	1.13
Water melon peels+Cow dung+Paw-paw peels+ Banana peels (W+C+P+B)	$^{1}/_{4}$W+ $^{1}/_{4}$C+$^{1}/_{4}$P+$^{1}/_{4}$B	9,523.81	0.229
N:P:K (15:15:15)		533.33 kg ha^{-1}	12.8 g/plant
Control (without bio-fertilizer and bioslurry)	Control		

between rows and 40 cm within a row and the plant population per plot was 25 plants (41,667 plants ha^{-1}) with 5 rows per plot.

The existing vegetation on the land was cleared off with machete, ploughed and harrowed into a fine tilt with a shovel. The pepper seedlings were raised in a heat-sterilized soil mixed with poultry manure at the ratio of 2:1 (soil: poultry manure) in plastic buckets for 5 weeks. The NPK 15:15:15 fertilizer was applied at the rate of 533.33 kg ha^{-1} (320 g/plot) to plots that require NPK 14 Days After Transplanting (DAT). Biofertilizer which was in slurry form was incorporated into the soil two weeks before transplanting based on the N-requirement of pepper. According to Grubben and Denton[19], pepper needs 80 kg N/ha. Based on this recommendation and rate of application, biofertilizer obtained from each substrate and its combinations was analyzed for N content. Based on the N content of each treatment, the bioslurry was applied as shown in Table 1.

Prior to seed bed preparation and after harvesting, composite soil samples were collected from 0-15 cm soil depth with the aid of soil auger from each experimental plot. The bioslurry were analyzed for nutrient contents[20] and soil sample were thoroughly mixed, air-dried and sieved through a 2 mm sieve and taken to the laboratory for analysis of physico-chemical properties using methods outlined by IITA[20]. Data were collected from 4 plants in the 2 inner rows of the net plot (0.24 m^2) at 2 weeks intervals over a period of 10 weeks starting from 4 Weeks After Transplanting (WAT) for growth and yield data including plant height, number of leaves, leaf area index, number of fruits, the weight of fresh and dry fruits per plant and yield.

Data collected were subjected to statistical analyses by using the Analysis of Variance (ANOVA) procedures for Randomized Complete Block Design (RCBD). Mean values were compared by using Duncan's Multiple Range Test (DMRT) at 0.05 level of probability when the F-ratio was significant.

RESULTS AND DISCUSSION

Nutrient composition of the soil and substrates used for the experiment: The physical properties of the soil before amendment with bio-fertilizer showed that the soil was mainly loamy sand in texture with 84% sand, 6% silt and 10% clay contents (Table 2). Similarly, the results for chemical properties before the application of bio-fertilizer showed that pH (H_2O) was 4.9 indicating that the soils were strongly acidic in reaction. The acidic condition observed might be due to the high rainfall amount that exceeds 2500 mm/annum in the studied soil including acid sand parent material on which the soil was developed[13]. The C:N ratio of 15:1 was obtained for the soil. Following critical nutrient ratings of Landon[21], total N (0.1%) and Effective Cation Exchange Capacity (ECEC) (5.1 cmol kg^{-1}) obtained for the experimental soil were low, organic carbon was moderate (1.5%), available phosphorus content was very high (38.3 mg kg^{-1}), exchangeable cations; Ca (4.2 cmol kg^{-1}), Mg (0.2 cmol kg^{-1}), K (0.1 cmol kg^{-1}) and Na (0.1 cmol kg^{-1}) were low. Previous study reported that essential nutrients such as; total N, organic C and exchangeable cations in coastal plain soils are mostly low[13]. The low total nitrogen, exchangeable cations (K, Ca and Mg) and ECEC in the experimental soil indicate low fertility status. Hence, there is a need for an additional supply of nutrients through bio-fertilization to improve the growth and yield of pepper.

Table 2: Physico-chemical properties of the soil before experiment

Physical properties	Value
Texture	
Sand (%)	84
Silt (%)	6
Clay (%)	10
Textural class	Loamy sand
Chemical properties	
pH(H_20)	4.9
Organic carbon (%)	1.5
Total nitrogen (%)	0.1
Available phosphorus (mg kg^{-1})	38.3
C:N ratio	15:1
Exch. Ca (cmol kg^{-1})	4.2
Exch. Mg (cmol kg^{-1})	0.2
Exch. K (cmol kg^{-1})	0.1
Exch. Na (cmol kg^{-1})	0.1
Exch. acidity Al^{+3} (cmol kg^{-1})	0.5
Exch. acidity H^+ (cmol kg^{-1})	0.3
CEC (cmol kg^{-1})	7.3
ECEC (cmol kg^{-1})	5.1
BS (%)	85.2

The mineral content of the substrates used for the experiment is presented in Table 3. The results showed that nitrogen and pH values were consistently higher after 45 days of digestion than they were in their initial form. Similarly, there was also an increase in the mineral contents of P, Na, Ca and Mg after 45 days of digestion while C:N ratios of all the substrates were low.

Effect of bio-fertilizer on soil chemical properties: The data on the effect of bio-fertilizer on soil chemical properties are presented in Table 4. Soil fertility interpretations are based on the critical limits of Landon[21]. The obtained result showed an increase in soil pH from strongly acidic (<5.5) in control soils and those applied with NPK to moderately acidic (6.0) in P amended soil, slightly acidic (6.1-6.5) in soils treated with B, W, B+W, C+W, B+P and C+P, neutral (6.6-7.3) in W+P and W+C+P+B amended soils and alkaline in C (8.2) and C+B (7.8) amended soils. This result is in line with the report of Oviyanti *et al.*[5], who demonstrated bio-fertilizer to have increased soil pH in their studies, but contrary to the studies of Berger *et al.*[22] that reported bio-fertilizers to have reduced soil pH, but increased the total N and available P and K. Except soil treated with W, the results obtained for organic carbon (OC) indicated an increase from low value (<1.5%) in control soils and those applied with NPK to moderate value (1.5-2.0%) in B, P and C amended soils and high values (>2.0%) in soils treated with B+W, W+P, C+W, B+P, C+P, C+B and W+C+P+B. The result obtained from this study is in line with the report of Abd El-Hamid *et al.*[23] that application of either organic amendments or bio-fertilizer as individual or combinations resulted in increased OM content and by extension OC in treated soil.

The obtained results for Total Nitrogen (TN) showed an increase in TN from low value (<0.2%) in control soils and those applied with NPK to moderate value in other treatments. Similarly, excepting W+P, B+W and C+W, there was a decrease in C:N ratios of other treated soils with W having the lowest C:N ratio value of 5:1. The implications of the narrow C: N ratios in the soils reflect high levels of microbial activities and rapid

Table 3: Mineral content and pH of the substrates used for the experiment

	Initial properties of substrate							Properties at 45 days after digestion								
		P	K	Na	Ca	Mg					P	K	Na	Ca	Mg	
Substrates	N (%)	(mg kg^{-1})	(cmol kg^{-1})				pH	OC (%)	C:N	N (%)	(mg kg^{-1})	(cmol kg^{-1})				pH
B	0.3	3.1	2.5	0.9	0.5	0.3	4.9	10.6	6.24	1.7	3.1	0.7	0.9	0.8	0.2	6.0
P	0.6	2.1	1.1	0.6	0.6	0.3	3.0	5.0	1.47	3.4	3.1	0.5	0.7	0.2	0.9	5.9
W	0.3	3.2	1.2	0.3	0.5	0.2	4.3	4.0	2.35	1.7	4.3	0.6	0.4	0.2	0.9	6.0
C	0.7	5.2	0.9	0.4	1.2	0.4	7.3	10.0	1.79	5.6	5.4	1.3	0.5	1.2	0.5	8.3
W+B	0.3	3.8	1.5	0.6	0.4	0.2	4.0	6.0	5.46	1.1	6.3	0.6	0.7	0.3	0.8	6.4
W+P	0.4	3.7	1.0	0.4	0.6	0.2	3.0	6.0	3.33	1.7	3.2	0.1	0.5	0.4	0.5	6.5
C+P	0.5	3.7	0.7	0.3	0.8	0.1	3.5	8.0	1.78	4.5	3.2	0.6	0.4	0.7	0.5	6.2
W+C	0.6	4.2	1.4	0.4	0.7	0.2	4.8	7.5	4.17	1.8	3.1	1.0	0.5	1.2	1.2	6.6
P+B	0.6	3.8	1.6	0.8	0.4	0.2	3.4	7.5	2.21	3.4	6.9	2.2	0.9	0.2	0.2	5.8
C+B	0.6	4.6	1.9	0.7	1.0	0.4	6.2	11.7	1.75	6.7	4.4	0.6	0.8	1.2	1.2	7.6
W+C+P+B	0.6	6.3	1.4	0.7	0.8	0.2	3.6	11.5	1.37	8.4	5.1	1.6	0.8	1.3	1.3	6.8

B: Banana peels, P: Paw-Paw peels, W: Water melon peels, C: Cow dung, W+B: Water melon+Banana peel, W+P: Water melon+Paw-paw peels, C+P: Cow dung+Paw-paw peels, W+C: Water melon+Cow dung; P+B: Paw-paw+Banana peels, C+B: Cow dung+Banana peels, W+C+P+B: Water melon peels+Cow dung+Pow-pow peels+Banana peels, OC: Organic carbon

Table 4: Chemical properties of the experimental soil after application of treatment

				C:N	AP	Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+	Al^{3+}	CEC	ECEC	
Treatments	pH	OC	TN (%)	Ratio	(mg kg^{-1})	(cmol kg^{-1})								BS (%)
B	6.1	1.6	0.2	8:1	38.3	5.1	0.4	0.1	0.3	0.5	0.3	7.1	6.7	88.1
P	6.0	1.6	0.2	8:1	37.4	4.3	0.4	0.3	0.3	0.5	0.3	7.1	6.1	86.9
W	6.1	1.4	0.3	5:1	38.1	4.6	1.0	0.3	0.5	0.5	0.2	9.2	7.1	90.1
C	8.2	1.5	0.2	8:1	34.4	4.0	1.1	0.4	0.4	0.5	0.3	7.0	6.7	88.1
B+W	6.5	2.8	0.2	14:1	37.7	5.8	1.2	0.6	0.7	0.5	0.1	7.5	8.9	93.3
W+P	6.7	2.4	0.2	12:1	40.1	5.0	1.2	0.6	0.6	0.5	0.4	7.8	8.3	89.2
C+W	6.2	2.7	0.2	14:1	38.3	4.7	0.6	0.6	0.4	0.5	0.3	7.1	7.1	88.7
B+P	6.1	2.7	0.3	9:1	37.2	5.2	0.7	0.6	0.6	0.5	0.3	7.4	7.9	89.9
C+P	6.2	2.9	0.3	10:1	38.2	4.6	1.1	0.6	0.6	0.6	0.5	7.7	8.0	86.3
C+B	7.8	2.9	0.3	10:1	38.3	5.6	1.1	0.6	0.6	0.6	0.5	7.6	9.0	87.3
W+C+P+B	6.8	3.4	0.3	10:1	40.1	5.8	1.1	0.9	0.6	0.5	0.3	8.0	9.2	91.3
NPK	4.8	1.2	0.1	12:1	30.1	3.2	0.3	0.6	0.2	0.5	0.1	6.4	4.9	87.8
Control	4.7	1.2	0.1	12:1	28.1	2.7	0.2	0.3	0.1	0.8	0.1	6.1	4.2	78.6

OC: Organic carbon, TN: Total nitrogen, Avail. P: Available phosphorus, CEC: Cation Exchange Capacity, ECEC: Effective cation exchange capacity, BS: Base saturation, C:N: Carbon:Nitrogen ratio, B: Banana peels, P: Paw-Paw peels, W: Water melon, C: Cow dung, W+B: Water melon+Banana peels, W+P: Water melon+Paw-paw peels, C+P: Cow dung+Paw-paw peels, W+C: Water melon+Cow dung, P+B: Paw-paw+banana peels C+B: Cow dung+Banana peels, W+C+P+B: Water melon peels+Cow dung+Paw-Paw peels+Banana peels

decomposition of organic matter. Although, the control soil was already high (28.1 mg kg^{-1}) in available phosphorus content, the obtained result showed an improvement in the available phosphorus contents of all the treated soils. Oviyanti *et al.*[5] demonstrated bio-fertilizer to increase potential K, K sorption, potential P, P sorption and total N in their studies.

Furthermore, soils treated with B, B+W, W+P, B+P, C+B and W+C+P+B showed increase in exchangeable Ca (>5 cmol kg^{-1}) compared with the control (2.7 cmol kg^{-1}) and NPK (3.2 cmol kg^{-1}) treated soils. The exchangeable potassium was also increase except in soils treated with B. Similarly, all the treated soils showed an enhancement in exchangeable Mg contents. This result is in line with Abd El-Hamid *et al.*[23] and Panhwar *et al.*[24] who reported that the application of bio-fertilizer significantly increase the exchangeable potassium, calcium and magnesium contents of the soil relative to the control. However, exchangeable acidity (H^+) was reduced in treated soils while Cation Exchange Capacity (CEC), Effective Cation Exchange Capacity (ECEC) and base saturation were increased in treated soils. Therefore, mark differences in soil chemical properties were observed between the control and other treatments with applications of bio-fertilizer. The results obtained in this study showed that the addition of bio-fertilizers has enhance the fertility status of the amended soils. This corroborated with the opinion of Fadila[25] that nutrient source with a mixture of organic material can enrich organic carbon and nutrient content of the soil thus in enhancing nutritional needs of plants.

Effect of bio-fertilizer on plant height: The effects of bio-fertilizer on the height of the pepper plant are shown in Table 5. The obtained result showed that the application of bio-fertilizer significantly ($p<0.05$) enhance the growth of pepper at 4, 6, 8 and 10 weeks after transplanting (WAT) in both wet and dry seasons relative to the control. At 4 WAT, the

Table 5: Effect of bio-fertilizer on height, number of leaves and leaf area index of hot pepper

	Plant height (cm)				Number of leaves				Leaf area index			
Season	4 WAT	6 WAT	8 WAT	10 WAT	4 WAT	6 WAT	8 WAT	10 WAT	4 WAT	6 WAT	8 WAT	10 WAT
Wet season												
B	18.53^{ab}	24.67^{a}	28.10^{a}	33.97^{bc}	28.33^{a}	41.67^{b}	62.67^{cde}	78.67^{b}	0.17^{a}	0.31^{b}	0.55^{cde}	0.77^{bcd}
P	21.63^{ab}	24.47^{ab}	29.63^{a}	35.90^{bc}	33.67^{a}	52.33^{a}	65.67^{cde}	79.67^{b}	0.16^{a}	0.28^{b}	0.38^{defg}	0.58^{cde}
W	19.57^{ab}	21.50^{ab}	26.30^{a}	33.63^{c}	19.33^{bcd}	27.67^{cd}	77.33^{bcd}	84.67^{b}	0.09^{bcd}	0.15^{b}	0.45^{def}	0.59^{cde}
C	21.07^{ab}	23.77^{ab}	29.57^{a}	36.80^{bc}	22.33^{b}	39.00^{b}	114.67^{ab}	136.33^{a}	0.12^{ab}	0.25^{b}	0.90^{ab}	1.43^{a}
W+B	16.37^{b}	17.70^{c}	30.03^{a}	34.50^{bc}	14.33^{de}	22.00^{de}	75.33^{bcd}	95.00^{b}	0.040^{def}	0.07^{b}	0.30^{efgh}	0.46^{def}
W+P	19.90^{ab}	21.43^{ab}	28.50^{a}	40.00^{abc}	16.00^{cde}	21.00^{d}	65.67^{cde}	89.67^{b}	0.043^{def}	0.08^{b}	0.32^{efgh}	0.62^{cde}
C+P	19.43^{ab}	21.57^{ab}	30.60^{a}	41.70^{ab}	15.67^{de}	22.00^{de}	127.67^{a}	148.00^{a}	0.067^{cdef}	0.11^{b}	0.65^{bcd}	0.93^{bc}
W+C	20.50^{ab}	24.53^{ab}	29.57^{a}	38.97^{abc}	15.00^{de}	26.00^{de}	87.33^{bc}	97.67^{b}	0.13^{ab}	0.19^{b}	0.73^{abc}	1.11^{ab}
P+B	18.67^{ab}	20.90^{b}	26.93^{a}	38.93^{abc}	14.67^{de}	22.33^{de}	53.33^{cde}	62.33^{b}	0.03^{f}	0.09^{b}	0.17^{fgh}	0.25^{ef}
C+B	19.47^{ab}	21.43^{ab}	28.83^{a}	40.80^{abc}	17.67^{bcde}	31.67^{c}	84.33^{bc}	97.00^{b}	0.10^{bc}	0.19^{b}	0.87^{ab}	0.66^{cde}
W+C+P+B	21.97^{a}	24.57^{ab}	30.97^{a}	45.30^{a}	21.00^{bc}	37.67^{b}	130.33^{a}	147.67^{a}	0.087^{bcde}	0.88^{a}	1.01^{a}	1.42^{a}
NPK	23.13^{a}	21.63^{ab}	30.17^{a}	39.70^{abc}	9.00^{f}	13.67^{e}	31.67^{e}	59.67^{b}	0.033^{ef}	0.07^{b}	0.14^{gh}	0.33^{ef}
Control	10.53^{c}	11.87^{c}	16.10^{b}	24.53^{d}	12.67^{ef}	21.67^{d}	36.33^{de}	81.67^{b}	0.043^{def}	0.02^{b}	0.06^{h}	0.14^{f}
Dry season												
B	15.00^{de}	15.77^{d}	26.23^{b}	36.13^{bc}	8.33^{cde}	13.00^{h}	37.67^{de}	69.7^{ef}	0.01^{e}	0.02^{d}	0.06^{g}	0.22^{ef}
P	18.07^{c}	20.27^{c}	26.73^{b}	36.97^{ab}	10.67^{bcd}	21.00^{g}	31.00^{f}	67.0^{f}	0.02^{cd}	0.05^{d}	0.08^{fg}	0.20^{ef}
W	13.20^{fg}	19.07^{c}	26.37^{b}	33.43^{cd}	11.67^{bcd}	32.00^{e}	65.33^{c}	82.7^{d}	0.01^{de}	0.04^{d}	0.10^{efg}	0.17^{f}
C	20.10^{b}	24.50^{b}	29.23^{a}	32.37^{d}	27.00^{a}	42.00^{cd}	83.67^{b}	117.0^{b}	0.04^{b}	0.07^{cd}	0.19^{d}	0.33^{d}
W+B	17.63^{c}	26.53^{a}	29.20^{a}	31.93^{d}	11.00^{bcd}	39.00^{d}	79.00^{bc}	105.7^{c}	0.02^{de}	0.08^{bcd}	0.19^{d}	0.28^{de}
W+P	14.70^{def}	15.53^{d}	18.80^{d}	21.63^{f}	8.67^{cde}	22.00^{fg}	35.33^{de}	84.7^{d}	0.01^{de}	0.04^{d}	0.08^{fg}	0.21^{ef}
C+P	18.60^{bc}	23.47^{b}	29.77^{a}	32.70^{d}	20.33^{a}	41.67^{cd}	122.67^{a}	154.3^{a}	0.03^{bc}	0.08^{bcd}	0.28^{c}	0.44^{c}
W+C	18.50^{bc}	20.33^{c}	23.77^{c}	28.37^{e}	9.33^{cde}	47.67^{bc}	76.33^{bc}	117.3^{b}	0.02^{cd}	0.11^{abcd}	0.20^{d}	0.33^{d}
P+B	13.47^{efg}	13.67^{e}	14.57^{e}	16.90^{g}	10.33^{bcd}	29.00^{ef}	46.33^{d}	78.0d^{e}	0.02^{de}	0.27^{ab}	0.13^{e}	0.22^{ef}
C+B	15.80^{d}	16.63^{d}	20.70^{c}	25.20^{e}	12.00^{bc}	52.00^{b}	78.33^{bc}	111.0^{bc}	0.06^{a}	0.26^{abc}	0.44^{b}	0.68^{b}
W+C+P+B	22.37^{a}	25.33^{ab}	30.73^{a}	39.73^{a}	13.67^{b}	62.67^{a}	146.67^{a}	183.3^{a}	0.06^{a}	0.30^{a}	0.75^{a}	1.03^{a}
NPK	14.53^{def}	15.80^{d}	17.80^{d}	20.30^{f}	7.67^{de}	30.00^{e}	44.00^{de}	107.3^{bc}	0.01^{de}	0.06^{d}	0.11^{ef}	0.30^{d}
Control	12.97^{g}	13.23^{e}	15.50^{e}	15.87^{g}	6.00^{f}	22.33^{fg}	35.00^{de}	84.0^{d}	0.01^{e}	0.03^{d}	0.07^{fg}	0.19^{f}

WAT: Weeks after transplanting, B: Banana peel, P: Paw-Paw peels, W: Water melon peels, C: Cow dung, W+B: Water melon peels+Banana peels, W+P: Water melon peels+Paw-paw peels, C+P: Cow dung+Paw-paw peels, W+C: Water melon peels+Cow dung, P+B: Paw-paw peels+Banana peels, C+B: Cow dung+Banana peels, W+C+P+B = Water melon+Cow dung+Paw-Paw peels+Banana peels, Means within a column not sharing a letter in common differ from other means significantly ($p<0.05$) following Duncan's Multiple Range Test (DMRT) application of W+C+P+B produced the tallest plants (21.97 cm), but was not significantly different from those observed in other treatments except for W+B and control soils in the wet season. Similarly, in the dry season, pepper plants on W+C+P+B amended soil had significantly ($p<0.05$) the tallest plant (22.37 cm) compared with those on control and other treatments amended soils. However, at 6 WAP in the wet season, pepper plant on B amended soil had the tallest plant (24.67 cm) and was statistically at par with those of other treatments, but significantly ($p<0.05$) different from those on control and W+B, P+B amended soils. Similarly, at 6 WAP during the dry season, soil amended with W+B had the tallest pepper plant (26.53 cm) compared with the control soil (13.23 cm) and was statistically at par with W+C+P+B (25.33 cm), but significantly different from those on other treatments. At 8 WAT, there were no significant ($p>0.05$) differences in plant height among the various treatments compared with the control soil in the wet season. Furthermore, in the dry season, pepper plant grown on W+C+P+B amended soil were the tallest plant (30.73 cm) which was at par with those observed in soil amended with C, C+P and W+B, but significantly different from those of other treatments. The result obtained at 10 WAT showed that plant height increased across all the treatments, with W+C+P+B producing the significant ($p<0.05$) tallest plants for both seasons. Nahed *et al.*[26] reported bio-fertilizer in their studies to increase the plant height of pepper (*Capsicum annum* L.) from 32 cm in unamended soils to 44.2 cm in treated soil. Similar results have been reported by Shaheen *et al.*[12] who asserted that treating pepper plants with bio-fertilizer causes significant increase in various growth attributes such as; plant height, weight and yield. Also, similar increase in plant height and other growth parameters were observed in different crops treated with bio-fertilizer[23,27]. The enhancement of pepper growth in this study is not surprising as Nofiyanto *et al.*[28] reported that bio-fertilizer contains bacteria that produces growth hormones such as trans-zeatin cytokines and auxin of Indole Acetic Acid (IAA), which is capable of stimulating seed germination and plant growth and development.

Effect of bio-fertilizer on number of leaves: The data on the effect of bio-fertilizer on the number of leaf of hot pepper is presented in Table 5. The results revealed that the number of leaves of pepper plants was significantly increased due to amendment of bio-fertilizer in both seasons of the experiment. At 4 WAT, soil amended with P gave the highest number of leaves (33.67), but was at par with B (28. 33) and significantly higher than those observed for other treatments and control soils in the wet season. Similarly, in the dry season, the number of leaves observed for pepper plants on soil amended with C and C+P were statistically at par, but was significantly ($p<0.05$) higher than those on control and other treatments amended soils. However, at 6 WAT in the wet season, pepper plant on P amended soil had more number of leaves than the control and other bio-fertilizer amended soils, whereas, in the dry season, pepper plant on W+C+P+B amended soil had the highest number of leaves compared with the control and other amended soils. Also, result obtained at 8 WAT showed the number of leaves observed for pepper plants in W+C+P+B amended soil to be statistically at par with C+P and C soils but significantly ($p<0.05$) higher than that observed for other treatments. However, at 10 WAT, the obtained results showed that the number of leaves increased across all the treatments, with C, C+P and W+C+P+B producing plant with the highest number of leaves in the wet season while C+P and W+C+P+B produced the highest number of leaves in the dry season. This is in agreement with the result of Nahed *et al.*[26] on the response of sweet pepper plants to some organic and bio-fertilizers, which in their studies had significantly more leaves than those grown in natural conditions. Studies by Fawzy *et al.*[10] also showed the application of bio-fertilizer to significantly increased the number of leaves of the pepper plant (*Capsicum annuum* L.) from 76 (control) to 81.5 in amended soils during the first planting season and 54.6 (control) to 57.51 in amended soils during the second planting season.

Effect of bio-fertilizer on leaf area index: The results on data for leaf area index at 4 WAT showed that soil amended with B gave the greatest leaf area index (0.17) and was statistically at par with soil amended with P and W+C, but significantly ($p<0.05$) greater than those recorded for the control soil including other treatments in the wet season. However, in the dry season, soil amended with C+B and W+C+P+B produced plants with the greatest leaf area index compared with other treatment amended soils. Similarly, at 6 WAT in the wet season, leaf area index recorded for pepper plant on soil amended with W+C+P+B was significantly ($p<0.05$) larger in leaf area index (0.88) than those on control and other treatments amended soils. However, in the dry season, leaf area index recorded for pepper plant on soil amended with W+C, P+B, C+B and W+C+P+B was statistically at par, but significantly ($p<0.05$) greater than those on control and other treatments amended soils.

Further results showed that at 8 WAT in wet season, leaf area index recorded for pepper plant on soil amended with C+B and W+C+P+B were statistically similar, but significantly ($p<0.05$) greater than those on control and other treatments

Table 6: Effect of bio-fertilizer on yield components and yield of hot pepper

Season	Treatments	NF/plant	WFF g/plot	WDF g/plant	YFF (t ha^{-1})	YDF (t ha^{-1})
Wet	B	71.33^{de}	30.87^{e}	8.13^{ef}	4.16^{f}	0.34^{def}
	P	71.33^{de}	34.13^{e}	7.50^{efg}	4.43^{f}	0.31^{def}
	W	39.00^{fg}	27.37^{e}	6.53^{fgh}	2.38	0.27^{def}
	C	102.3^{bc}	74.57^{c}	9.10^{de}	6.74^{cd}	0.38^{de}
	W+B	87.33^{cd}	72.07^{c}	9.77^{de}	5.89^{de}	0.41^{de}
	W+P	115.33^{ab}	70.50^{c}	5.80^{ghi}	5.00^{ef}	0.24^{ef}
	C+P	115.33^{ab}	99.92^{b}	18.53^{b}	3.65^{fg}	0.63^{cd}
	W+C	105.33^{bc}	72.50^{c}	14.33^{c}	8.02^{bc}	0.60^{b}
	P+B	60.00^{ef}	55.17^{d}	10.93^{d}	6.49^{d}	0.59^{bc}
	C+B	106.33^{bc}	93.37^{b}	18.27^{b}	7.04^{cd}	0.76^{b}
	W+C+P+B	124.67^{ab}	113.30^{a}	30.13^{a}	13.61^{a}	1.33^{a}
	NPK	130.67^{a}	47.03^{d}	4.43^{hi}	8.77^{b}	0.42^{de}
	Control	66.00^{de}	26.27^{e}	3.63^{i}	3.71^{gh}	0.18^{f}
Dry	B	20.33^{de}	19.10^{de}	6.233^{b}	0.79^{de}	0.26^{b}
	P	17.00^{def}	17.63^{def}	4.900^{c}	0.74^{def}	0.20^{c}
	W	16.33^{def}	16.37^{ef}	3.967^{d}	0.68^{ef}	0.17^{d}
	C	25.33^{cd}	25.67^{c}	6.400^{b}	1.07^{c}	0.27^{b}
	W+B	21.00^{de}	20.37^{de}	6.333^{b}	0.85^{de}	0.26^{b}
	W+P	18.67^{def}	18.20^{def}	4.900^{c}	0.76^{def}	0.20^{c}
	C+P	29.33^{bc}	29.77^{bc}	6.600^{b}	0.82^{de}	0.23^{c}
	W+C	33.33^{ab}	33.57^{ab}	6.500^{b}	1.24^{bc}	0.28^{ab}
	P+B	21.00^{de}	19.87^{de}	5.467^{c}	1.34^{ab}	0.28^{ab}
	C+B	28.33^{c}	28.50^{c}	6.633^{b}	1.19^{c}	0.28^{ab}
	W+C+P+B	35.33^{a}	35.53^{a}	8.400^{a}	1.48^{a}	0.29^{a}
	NPK	15.67^{ef}	21.17^{d}	5.067^{c}	0.88^{d}	0.21^{c}
	Control	14.33^{f}	14.27^{f}	3.733^{d}	0.59^{f}	0.16^{d}

NF: Number of fruit, WFF: Weight of fresh fruit, WDF: Weight of dry fruit, YFF: Yield of fresh fruit, YDF: Yield of dry fruit, B: Banana peel, P: Paw-Paw, W: Water melon, C: Cow dung, W+B: Water melon+Banana peel, W+P: Water melon+Paw-paw, C+P = Cow dung+Paw-paw, W+C: Water melon+Cow dung, P+B: Paw-paw+Banana; C+B: Cow dung+Banana, W+C+P+B: Water melon+Cow dung+Paw-Paw peel+Banana peel, Means within a column not sharing a letter in common differ from other means significantly (p<0.05) following Duncan's Multiple Range Test (DMRT)

amended soils, while in dry season only soil amended with W+C+P+B had the greatest leaf area index that was significantly (p<0.05) greater than those on other treatments. Nevertheless, at 10 WAT in the wet season, leaf area index recorded for pepper plant on soil amended with C, W+C and W+C+P+B were statistically at par, but significantly (p<0.05) greater than those on control and other treatments amended soils. However, in the dry season, leaf area index recorded for pepper plant on soil amended with W+C+P+B was significantly (p<0.05) greater than those on control and other treatments amended soils. Nahed *et al.*[26] also had significantly wider leaf area for both planting season in their studies.

Effect of bio-fertilizer on number of fruit per plant: The results of the effect of the applied bio-fertilizers on the number of pepper fruits produced per plant are presented in Table 6. Except for soil amended with W and P+B, the number of fruits obtained from soil treated with single or combined bio-fertilizers exceeded those of the control soil in both wet and dry seasons. The highest total number of fruits per plant during the wet season was obtained from soils treated with NPK which was statistically at par with soil amended with W+C+P+B, C+P and W+P, but significantly different from other treatments. However, during the dry season, only soil amended with W+C+P+B produced the highest number of fruits which was significantly different from other treatments. The results confirmed previous findings that the addition of bio-fertilizer and other organic amendments increased the productivity of pepper plant[10,12]. The vigorous increase in number of fruit of capsicum frutescence could also be attributable to supply of nitrogen contained in the bio-fertilizers sources. This is supported by the opinion of Hayati *et al.*[29] which stated that organic fertilizer is the main source of macro-nutrients such as; N, P, K, Ca, Mg and S as well as essential micro-nutrients to enhance vegetative and generative growth of chili plants.

Effect of bio-fertilizer on weight of fresh fruit of pepper per plant: The weight of fresh fruit obtained from soils treated with the bioslurry and NPK fertilizer was significantly higher than the unamended plots during both seasons of investigation (Table 6). The highest weight of fresh fruits during the wet season was associated with the soil amended with W+C+P+B and was significantly different from other treatments and the control. This confirmed that, the application of bio-fertilizer, especially from different substrates

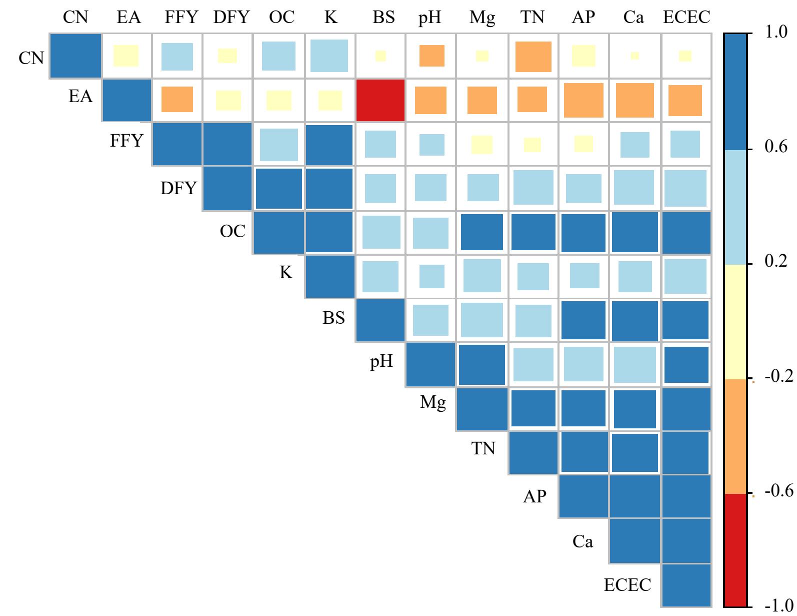

Fig. 2: Relationship between yield of pepper and soil chemical properties

FFY: Yield of fresh fruit of pepper (t ha^{-1}), DFY: Yield of dry fruit of pepper (t ha^{-1}), OC: Organic carbon (%), CN: Carbon: nitrogen ratio; TN: Total nitrogen (%), AP: Available phosphorus (mg kg^{-1}), Ca: Exc. Ca (cmol kg^{-1}), Mg: Exc. Mg (cmol kg^{-1}), K: Exc. K (cmol kg^{-1}), EA: Exchangeable acidity (cmol kg^{-1}), ECEC: Effective cation exchange capacity (cmol kg^{-1}), BS: Base saturation (%)

was able to significantly increase fresh fruit weight of pepper. Also, during dry season, the highest weight of fresh fruits was obtained from soils treated with W+C+P+B and was statistically at par with soil amended with W+C but significantly ($p<0.05$) different from other treatments. The results agreed with those obtained by Shaheen *et al.* [12] and Fawzy *et al.*[10].

Effect of bio-fertilizer on weight of dry fruit of pepper per plant: The result of the effect of bio-fertilizer on the dry weight of pepper as presented in Table 6 showed that the highest weight of dry fruits for both dry and wet seasons was obtained in soils amended with W+C+P+B and was significantly different from other treatments and the control. This result corroborated the findings of Nahed *et al.*[26] who reported bio-fertilizer in their study to significantly ($p<0.05$) increased the weight of fresh and dry fruits of pepper.

Effect of bio-fertilizer on yield of fresh fruit of pepper per plant: In the wet season, the combined application of bio-fertilizer including NPK significantly increased the yield of fresh fruit of pepper in comparison with the control. Soil amended with W+C+P+B resulted in significantly ($p<0.05$) higher fresh fruit yield in comparison with other treatments. Furthermore, the results obtained for dry season showed that the yield of fresh pepper on soil amended with P+B and W+C+P+B were statistically at par, but significantly ($p<0.05$) higher than those on control and other biofertilizer amended soils. The results from previous studies by Abd El-Hamid *et al.*[23] on wheat plants and peanut plants, Shaheen *et al.*[12] on sweet peper, Abdel-Hakim *et al.*[27] on new pea (*Pisum sativum* L.) cultivars, all recorded results that are in good agreement with that obtain herein. The increase in yield under this study may be ascribed to increase in weight per fruit, as a result of improvement in the number of fruit which was attributable to N, P, K, Ca and Mg contents of the biofertilizer utilized. Furthermore, the yield obtained in this study could also be due to influence of other yield attributes such as; number of leaf area index, number of fruits per plant and fruit weight.

Effect of bio-fertilizer on yield of dry fruit of pepper: The obtained results for the yield of dry fruit of pepper during wet season showed that soil amended with W+C+P+B had significantly ($p<0.05$) higher dry fruit of pepper than control and other bio-fertilizer amended soil. However, in the dry season, the yield of dry pepper on soil amended with W+C, P+B, C+B and W+C+P+B were statistically at par but significantly ($p<0.05$) higher than those on control and other bio-fertilizer amended soils. The result obtained for yield of dry fruit of pepper is also in agreement with previous studies[11,12].

The results obtained from this study are in accordance with the hypothesis that good conditions of the soil chemical properties should correspond with good yields[30]. Findings in this research showed optimal soil conditions in terms of pH, OC, TN, C: N ratio, available phosphorus, exchangeable cations (Ca, Mg and K) including base saturation.

Relationship between yield of pepper and soil chemical properties: Results of correlation analysis between the yield of pepper and soil chemical properties are presented in Fig. 2. In Fig. 2, deep blue coloured boxes showed positive and strong correlation (1-0.6 in the bar), light blue boxes showed strong to weak positive correlation (0.6-0.2 in the bar), red box showed strong and negative correlation (-1 to -0.6 in the bar), brown boxes showed strong to weak negative correlation (-0.6 to -0.2 in the bar). Strong and positive correlations was observed between fresh fruit yield (FFY) of pepper and exchangeable K ($r = 0.75$, $p<0.01$). Similarly, strong and positive correlations were observed between dry fruit yield (DFY) of pepper and organic carbon (OC) ($r = 0.76$, $p<0.01$), exchangeable K ($r = 0.75$, $p<0.01$), effective cation exchange capacity (ECEC) ($r = 0.59$, $p<0.05$). In addition, a positive correlation, although not significant ($p>0.05$) was found between FFY and pH ($r = 0.22$), OC ($r = 0.49$), C:N ratio ($r = 0.33$), Ca ($r = 0.29$), ECEC($r = 0.32$) and BS ($r = 0.36$). Also, an interesting positive relationship were observed between DFY and pH ($r = 0.33$), TN ($r = 0.55$), AP ($r = 0.41$), Ca ($r = 0.55$), Mg ($r = 0.34$) and BS ($r = 0.37$). In particular, as expected, an inverse relationships between FFY and Exchangeable Acidity (EA) ($r = -0.29$, $p > 0.05$) and DFY and EA (($r = -0.19$, $p>0.05$) were detected as well as between BS and EA ($r = -0.87$, $p<0.01$) and pH and EA ($r = -0.35$, $p>0.05$). As expected, decreasing values of exchangeable acidity should match with an increasing base saturation and yield of pepper in the studied soil. This is in agreement with Opala *et al.*[31] who indicated in their studied that applying organic materials in the soil decreased exchangeable acidity which in turn increased soil pH. Agronomic results of this investigation showed average yield of pepper for W+C+P+B amended soil to be comparable to FAO[32] average yield of 13.4 t ha^{-1}. A reasonable positive and significant ($p<0.05$) relationship between pH and Available Phosphorus (AP) ($r = 0.56$), Ca ($r = 0.58$), Mg ($r = 0.75$) and ECEC ($r = 0.67$) were also detected. Similarly, there was a strong positive significant ($p<0.05$) correlation between OC and AP ($r = 0.68$), Ca ($r = 0.79$), Mg ($r = 0.62$) and K ($r = 0.77$). Further results showed strong positive significant correlation between TN and OC ($r = 0.65$), AP ($r = 0.75$), Ca ($r = 0.72$), Mg ($r = 0.64$) and ECEC ($r = 0.78$). The result implied that as pH, OC and TN increases, the observed soil chemical properties also increase correspondingly.

CONCLUSION

The trial have shown the efficacy of bio-fertilizer as good organic amendments in the soil for enhanced growth and yield of pepper and improvement of soil chemical properties. The best treatment was bioslurry obtained from combinations of watermelon peels+cow dung+paw-paw peels+banana peels which consistently increased plant height, number of leaves, leaf area index, weight of fresh and dry fruit and yield of pepper including improvement of soil quality. Hence, the application of this biofertilizer could substitute NPK fertilizer in marginal soils which characterizes coastal plain sands of humid tropical rainforest of Calabar, Nigeria.

SIGNIFICANCE STATEMENT

This study revealed that the combine use of organic waste obtained from cow dung (C), banana (B), watermelon (W) and paw-paw (P) fruit peels was beneficial for bio-fertilizer production for enhance pepper production. Current research work will assist agronomist, farmers and researchers at large to uncover the beneficial effect of bio-fertilizer on soil properties, crop growth and yield and hence, environmental benefit of its utilization compared with conventional use of chemical fertilizers. Therefore, a quick and useful method of waste management and utilization in the mega city of Calabar where waste generation is on the increase is uncovered.

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